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# Benefits of Using the Photosimulation Laboratory Environment for Camouflage Assessment

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## ABSTRACT

A method is described for using the photosimulation laboratory environment to evaluate the effectiveness of camouflage for military vehicles. There are distinct advantages to acquiring images at the field site and then bringing them back for observer testing in a laboratory environment. Laboratory testing provides a repeatable, secure, and low-cost way to generate realistic performance data for vehicle evaluation for the purposes of signature testing, measurement of the effectiveness of camouflage relative to a baseline vehicle, and calibration and validation of target acquisition models. A test is described by the authors in which a baseline LAV is compared to a treated LAV in the TARDEC Visual Perception Laboratory using imagery collected from the field in the manner prescribed by an experimental design.

## INTRODUCTION

High-resolution digital cameras presently available on the market are rapidly approaching the quality of film resolution. Five and six megabyte CCD imaging chips in combination with the ability to capture imagery in raw 24-bit format, combined with large memory storage devices enable high resolution imagery to be captured at field site locations. Using high-resolution graphics projectors, the imagery can be presented in the controlled environment of the lab in such a manner as to obtain observer data with confidence levels approaching 99%. It is the authors opinion that, the benefits of the high degree of confidence achieved using the repeatability offered by the lab environment, far outweighs any perceived advantage of having multiple teams of observers present at the field location to search for vehicles.

The Light Armored Vehicle (LAV) Family of Vehicles (FOV) was developed to provide the Marine Corps with enhanced mobile warfare capabilities. General Motors, Diesel Division in London, Ontario, Canada, began manufacturing the LAV FOV in 1982 and completed delivery to the USMC in April 1988. The LAV FOV includes several variants which utilize light armor protection from small arms, light machine gun fire, artillery projectile fragments, and mine fragments. Each variant was designed for a specific mission function and was mounted on a common chassis. The LAV FOV consists of direct fire variants armed with 25mm guns (LAV-25), with TOW II Missiles on LAV Anti-Tank (LAV-AT), an Air Defense variant (LAV-AD) capable of providing air defense coverage for the LAR unit, and support variants consisting of Command and Control (LAV-C2), Mortar (LAV-M), Logistics (LAV-L), and Recovery (LAV-R) vehicles.

The LAV is a highly mobile vehicle for conducting reconnaissance, counter reconnaissance, limited offensive and defensive operations and other missions. The current LAV is increasingly difficult to maintain at acceptable levels of readiness as it nears the end of its original projected service life. Budget constraints prevent the development and fielding of a new vehicle capable of performing its assigned missions. The main purpose of the Light Armored Vehicle Service Life Extension Program (LAV-SLEP) is to address the major subsystems that are currently degrading readiness or are driving higher than necessary O&S costs. The LAV retains the same requirements for performance capabilities and characteristics in the areas of mobility, lethality, survivability, and sustainability.

The test described in this report was undertaken as part of the LAV-SLEP. Specifically, the purpose of this field test was to determine the performance of a treatment known as ADCAM in reducing the probability of detection in the visual part of the electromagnetic spectrum at unity magnification (as seen by the naked eye) at various ranges, aspect angles and lighting conditions. Only the baseline results will be described in this report because comparisons of the treated versus untreated are classified.

# METHOD

The test design implemented was an extension of visual detection requirements provided to our lab from PM LAV. Initially the PM requested only two range points at standard engagement ranges. We suggested having more ranges in between the critical range points to obtain a probability of detection versus range curve, as is more typical for these kinds of tests. A test matrix was developed in full-factorial form and 24-bit color imagery was collected using a Kodak 460 digital camera. The images were prepared for the photosimulation test and then presented to 30 subjects. The experimental factors and levels with their values are shown below in Table 1. The photosimulation test in the lab was arranged so that a pixel IFOV subtended by the display was less than one minute of arc and the displayed image represented a unity magnification or 1X representation to the subject. The first test was meant to emulate naked-eye vision. Prior to the actual test, the subjects were instructed on the purpose of the test as well as required to take a pre-test in which they could become familiar with the imagery and software. None of the pictures used in the pre-test were used in the actual test, however, the images were from the same set. The test procedure was to display an image with a time-out of 30 seconds. The imagery is cropped so that no scrolling is required. The target can appear within one of five possible regions. The soldier must use the mouse to "click-on" what her or she thinks is a target, based on the training.

Analysis of the first test showed most subjects obtained a score of only 20 % detection. This is not unreasonable given the difficulty of the imagery. The ranges are not unusual for such a test, however the high degree of clutter and in particular the height of the grass on the terrain makes it difficult for the unaided eye to detect common cure features of the vehicle. A second test was arranged at a power of 3X. The imagery from the field was of sufficient resolution so that there was no noticeable increase in pixelation of the imagery an in increase in magnification. The presentation in the lab was randomized, this is a very good reason to use the lab.

| Region | | |
|---|---|---|
| | 1 | Top-Left |
| | 2 | Top-Right |
| | 3 | Lower-Left |
| | 4 | Lower-Right |
| | 5 | Center |

| Vehicle Type | | |
|---|---|---|
| | 1 | Baseline (old LAV) |
| | 2 | SLEP + ADCAM |
| | 3 | SLEP + ADCAM - ADCAM bowplane |

| Aspect angle | | |
|---|---|---|
| | 1 | Front |
| | 2 | 30 degree |
| | 3 | Side |

| Lighting | | |
|---|---|---|
| | 1 | Front Lit |
| | 2 | Back Lit |

| Weather condition | | |
|---|---|---|
| | 1 | Clear |
| | 2 | Overcast |

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| Range (km) | |
|---|---|
| 1 | 1 |
| 2 | 1.5 |
| 3 | 2 |
| 4 | 2.5 |
| 5 | 3 |

Table 1: Factor matrices for the visual detection test

At this point, it's instructive to digress for a moment to emphasize the rationale for using the type of design methodology described by the authors in this paper. Statistically based experimental design is a strategy of designing experiments in such a manner as to develop a robust test plan. In other words, a test plan that is minimally affected by external sources of variability. What makes vehicle field test challenging is that there are many variables that are present and must be accounted for. In addition, the variables interact with each other. The correct approach to working with several factors is to conduct a factorial experiment. A factorial experiment is an experimental strategy in which the factors are varied together, rather than one at a time. The factorial experimental design concept is extremely important and powerful when used correctly. Entire books are written on how to choose an experimental design based on considerations such as time, money and availability of materials. Montgomery wrote a book that is a standard in the field of experimental design.[1] For the type of tests that the authors are involved with, it is dangerous to leave out data points in the hope of making the test plan more expedient. Attempts to do just that in the past have resulted in things such as the 'heartbeat effect' in data. The range of variability in the factors is so great and interdependent, that experimental designs such as fractional factorial designs are to be avoided.

When making inferences about differences in a factor in a perception experiment in the laboratory we want to make the experimental error as small possible. This requires that we remove the variability between subjects from the experimental error. The design we use to accomplish this is a factorial experiment run in a randomized complete block. By using this design with the subjects as blocks we form a more homogeneous experimental unit on which to compare different factors. This experimental design improves the accuracy of the comparisons among the different factors by eliminating the variability among the subjects. Within a block, the order in which the treatment combinations are run is randomly determined. It is usually not possible to implement this experimental design in the context of a traditional field test.

The pictures below in Fig. 1 through Fig. 6 were used for training observers as to what kind of vehicles they would be looking for.
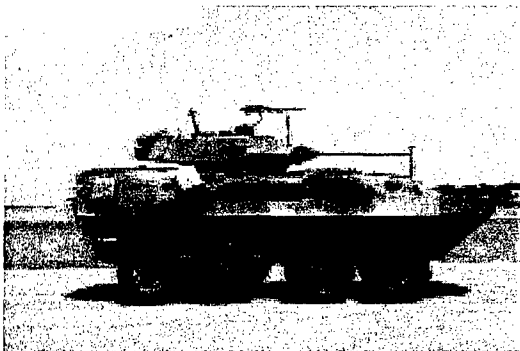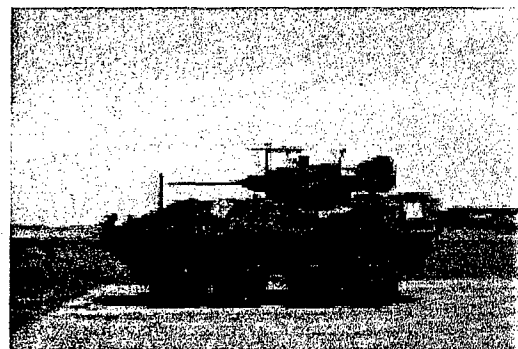


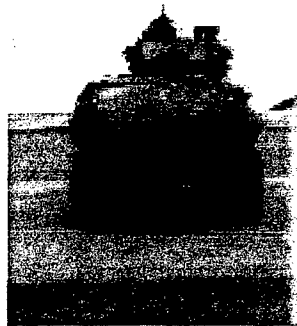Fig. 1: Baseline side



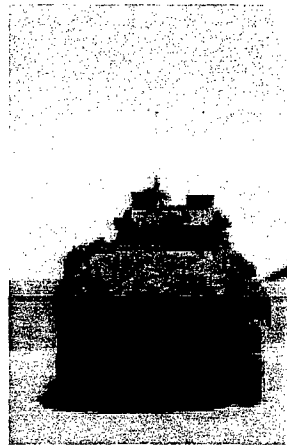Fig. 2: ADCAM side

Fig. 3: Baseline front
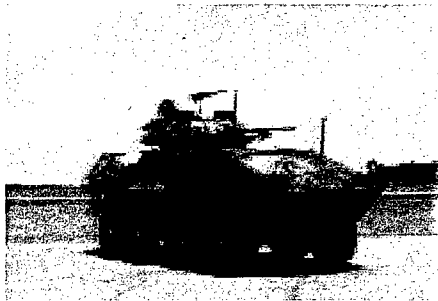

Fig. 4: ADCAM front


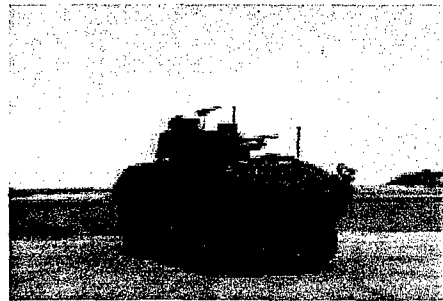Fig. 5: Baseline at 30 degrees


Fig. 6: ADCAM at 30 degrees

The figure below is of the background at the field site and does not have a vehicle in it. The grass height was high at the test site.


Fig. 7: View of the test field

The charts in Fig. 8 below show the results of measuring the X and Y chromaticity values of the monitors that were used in the test. The values measured were compared to standard values and found to be virtually identical.
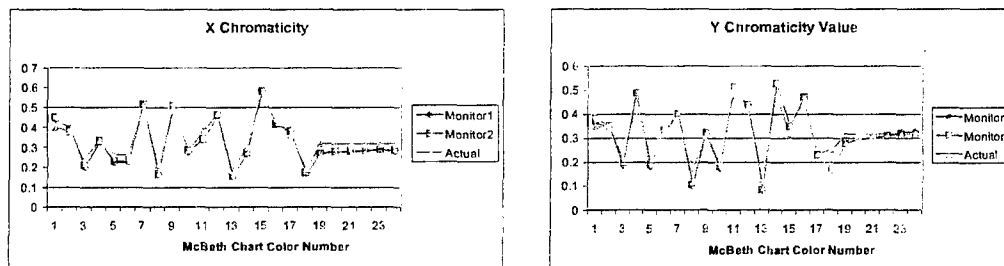


Figure 8: X and Y monitor chromaticity calibration charts

## ANALYSIS

Below in Table 2 is the ANOVA table for the baseline vehicle and the other experimental factors. The treated vehicle has been excluded because of security classification. The power of the experimental design methodology is shown here in that the significance of individual factors and of their interactions are available. Using this kind of a test, one can obtain not only a model curve of the detection probability versus any factor in the test, but, one can also obtain the relative importance of the individual factors.

**Tests of Between-Subjects Effects**

Dependent Variable: RANK of RESPONSE

| Source | Type IV Sum of Squares | df | Mean Square | F | Sig. | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|
| Corrected Model | 185215009[b] | 89 | 2081067.514 | 26.782 | .000 | 2383.607 | 1.000 |
| Intercept | 1159759015 | 1 | 1159759015 | 14925.408 | .000 | 14925.408 | 1.000 |
| SKY_COND | 2918024.068 | 2 | 1459012.034 | 18.777 | .000 | 37.553 | 1.000 |
| RANGE | 161301308 | 9 | 17922367.58 | 230.650 | .000 | 2075.852 | 1.000 |
| ASPECT | 944347.896 | 2 | 472173.948 | 6.077 | .002 | 12.153 | .887 |
| SKY_COND * RANGE | 5751990.053 | 18 | 319555.003 | 4.112 | .000 | 74.025 | 1.000 |
| SKY_COND * ASPECT | 2459473.720 | 4 | 614868.430 | 7.913 | .000 | 31.652 | .998 |
| RANGE * ASPECT | 6204854.010 | 18 | 344714.112 | 4.436 | .000 | 79.853 | 1.000 |
| SKY_COND * RANGE * ASPECT | 5397720.861 | 36 | 149936.691 | 1.930 | .001 | 69.465 | 1.000 |
| Error | 128521871 | 1654 | 77703.671 | | | | |
| Total | 1641367780 | 1744 | | | | | |
| Corrected Total | 313736880 | 1743 | | | | | |

a. Computed using alpha = .05

b. R Squared = .590 (Adjusted R Squared = .568)

Table 2: ANOVA of test factors

Figure 9 shows the model generated logistic curve of the probability of detection of the baseline LAV. This curve has the effects of all the various factors 'rolled-up' into it.
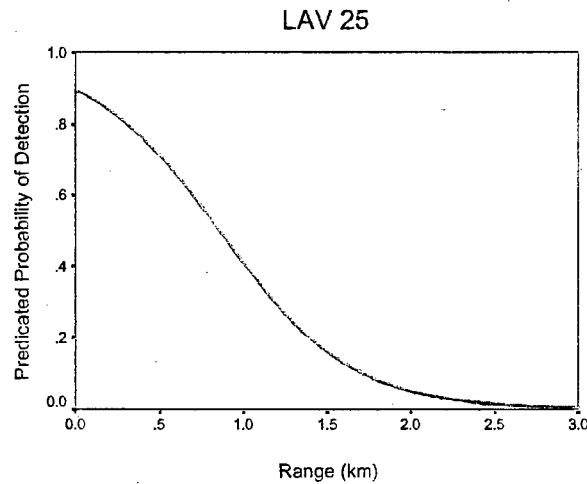
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LAV 25

Fig. 9 : Logistic curve fit to the model from the subject responses

## Fuzzy Logic Modeling of the DATA

The Fuzzy Logic Approach (FLA) was also used to model the experimental observer response detection data. The FLA and it's application to modeling the probability of detection is described in other papers by the authors. [2,3] The main elements of the model as applied to this test are shown below. The correlation obtained in this test was 0.9 between the experimental result and the FLA model predicted value. The 0.9 correlation is between the model built from half the data set and half used as testing. Figures 10 to 13 show the several interfaces that are part of the FLA model and the resulting output surface.
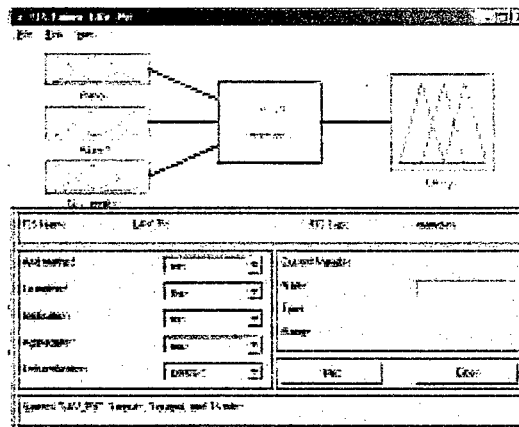


Fig. 10. FLA Fuzzy Inference Main Module

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Fig. 11: FLA membership functions
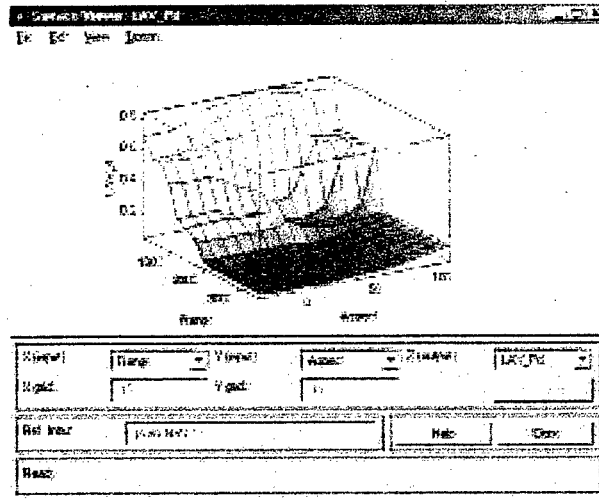
Fig. 12: FLA firing diagram

Fig. 13: Resulting model surface of Probability of detection versus range and aspect angle

## Conclusions

An experimental design method was used to design an imagery collection test plan and a laboratory testing procedure. The probability of detection was determined for the baseline and treated vehicles. A statistical model was made of the laboratory results that gave probability of detection versus range. A fuzzy logic model was also made from the data that had 0.9 correlation to data not used in the training set.

An advantage of using the photosimulation lab environment is that we are able to archive scenes used in the simulation. Therefore, at a later time we are able to rerun the same test on a different subject pool. The new subjects may have a different training and the images may also be modified by either magnification or adding atmospheric conditions. This provides tremendous cost savings since we do not have to pay for another field test.

## References

[1] Montgomery, C. Douglas, **Design and Analysis of Experiments**, Fourth Edition, John Wiley & Sons, New York, NY, 1997.

[2] Meitzler, T., Sohn, E., Singh, H., Elgarhi, A., and Nam, D., Predicting search time in visually cluttered scenes using the fuzzy logic approach," Opt. Eng., 40(9), Sept. 2001, pp. 1844-1851.

[3] Meitzler, T, Singh, H., Arefeh, L., Sohn, E., and Gerhart, G., "Predicting the Probability of target detection in static infrared and visual scenes using the fuzzy logic approach," Opt. Eng., Vol. 37 (1), Jan. 1998.